Kansas Department of Health and Environment

Report of Radiological Environmental Monitoring of the Environs Surrounding

Wolf Creek Generating Station

July 2013-June 2014

Division of Public Health, Bureau of Environmental Health

Radiation and Asbestos Control Section

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Contents

Introduction

Wolf Creek Generating Station (WCGS) is a pressurized water nuclear reactor capable of producing over 1,200 megawatts of electrical power. Located near Burlington Kansas, the plant is operated by Wolf Creek Nuclear Operating Corporation (WCNOC). The facility releases radioactive material to the environment in the form of liquid and gaseous effluents. This report details the results of surveillance of the environs surrounding WCGS conducted by the Kansas Department of Health and Environment (KDHE) from July 1, 2013 through June 30, 2014.

KDHE's Wolf Creek Environmental Radiation Surveillance (ERS) program began in 1979 in accordance with Kansas Administrative Regulation (K.A.R.) 28-19-81 with the initial selection of surface water sampling locations. The ERS program parallels (and partially overlaps) the WCNOC Radiological Environmental Monitoring Program (REMP).

The purpose of the ERS program is to detect, identify, and measure radioactive material and direct radiation released to the environment from the operation of WCGS. Data indicating the release of elevated levels of radioactive material will be used to determine the need for corrective and/or protective actions to protect the health and safety of the public.

The ERS program includes the following monitoring methods:

- Measurement of ambient external radiation levels using optically stimulated luminescence dosimeters
- Monitoring of radionuclides present in ambient air through weekly collection and laboratory analysis of continuous air samples
- Monitoring of radionuclides present in water, terrestrial vegetation, aquatic vegetation, fish, sediments, and soil through scheduled and random sample collection and laboratory analysis.

Results Summary

The most significant radionuclide present in surface water samples collected in the Coffey County Lake is tritium (^{3}H), a beta emitter. The highest ^{3}H concentration measured in the Coffey County Lake during SFY 2014 was 15,635 pCi/l in March, 2014. This maximum Coffey County Lake ^{3}H concentration is 76% of the National Primary Drinking Regulation maximum contaminant level (MCL) of 20,000 pCi/l. *The water from the Coffey County Lake is not used as a drinking water source*. The average CCL surface water ^{3}H concentration for SFY 2014 was 11,742 pCi/l, or 59% of MCL. Coffey County Lake is not approved for any aquatic recreation other than fishing. All other non-CCL surface water and offsite ground water samples collected in the environs of WCGS during SFY 2014 indicated no radionuclides present attributable to the operation of WCGS.

Aquatic vegetation samples are the best indicators for monitoring the seasonal fluctuations of fission and activation product levels in the Coffey County Lake. No aquatic vegetation sample showed any nuclides attributable to WCGS operation. Five trending samples and six random samples were analyzed.

Sediment samples have been excellent indicators for the long-term buildup of fission and activation product activity levels in the Coffey County Lake. The highest fission product activity in sediments during SFY 2014 was 150 pCi/kg-dry ^{137}Cs in a bottom sediment sample from the John Redmond Reservoir. No sediment samples showed any nuclides attributable to WCGS operation.

Airborne sample analysis indicated that no radionuclides attributable to the operation of WCGS were present above the lower limits of detection during SFY 2014.

Sample analysis of aquatic vegetation, offsite ground water, sediments, terrestrial vegetation, soil, milk, grain, and vegetable samples collected in the environs of WCGS during SFY 2014 indicated no radionuclides present attributable to the operation of WCGS.

Samples of nine species of fish were taken from the Coffey County Lake during SFY 2014. Sample analysis of edible fish portions collected in the environs of WCGS during SFY 2014 indicated that no gamma emitters attributable to WCGS operation were present. The highest ^{3}H concentration in tissue was 10,421 pCi/kg-wet found in a white bass sample taken from the CCL. Using an ICRP 30 dose conversion factor for ingestion ($h_{E,50}$) of $6.40X10^{-8}$ mrem per pCi ^{3}H ingested, a standard man consuming 21 kg/y of fish containing 10,421 pCi/kg ^{3}H would receive a committed effective dose equivalent of 0.014 mrem. The projected dose equivalent is far below the 100 mrem/yr regulatory limit for a member of the public.

Data from direct radiation monitoring sites revealed no significant changes from preoperational data. The lowest direct radiation levels are found closest to the WCGS. The direct radiation

levels on the Coffey County Lake baffle dikes at the 1,200 m exclusion area boundary are the lowest of any monitored site. The limestone used to construct the baffle dikes has a lower natural background radioactivity than the original soil present before the construction of the Coffey County Lake. This effect of construction on the terrestrial component of natural background radiation was noted on radiation surveys conducted around the WCGS site before bringing the initial fuel load on the site. The water from the Coffey County Lake also acts as an effective shield from terrestrial radiation that was present before Coffey County Lake filling.

The ratio of KDHE results to WCNOC results ranged from 1.0-1.5. A summary of comparison data may be found in the Results Comparison Table.

Results Summary Table

Type of Sample	Number of Sampling Stations	Total Samples Collected
Air (particulate and iodine)	5	520
Soil	5	5
Random Soil	10	10
Direct Radiation	31	248
Surface Water	5	39
Offsite Ground Water	6	23
Onsite Ground Water	3	10
Sediments	5	13
Random Sediments	16	16
Aquatic Vegetation	6	7
Random Aquatic Vegetation	6	6
Milk	2	8
Fish	2	20
Game Animals/Domestic Meat	0	1
Terrestrial Vegetation/Human, Animal Food	8	9
Random Terrestrial Vegetation/Human, Animal Food	10	10
Total	**120**	**945**

Results Comparison Table

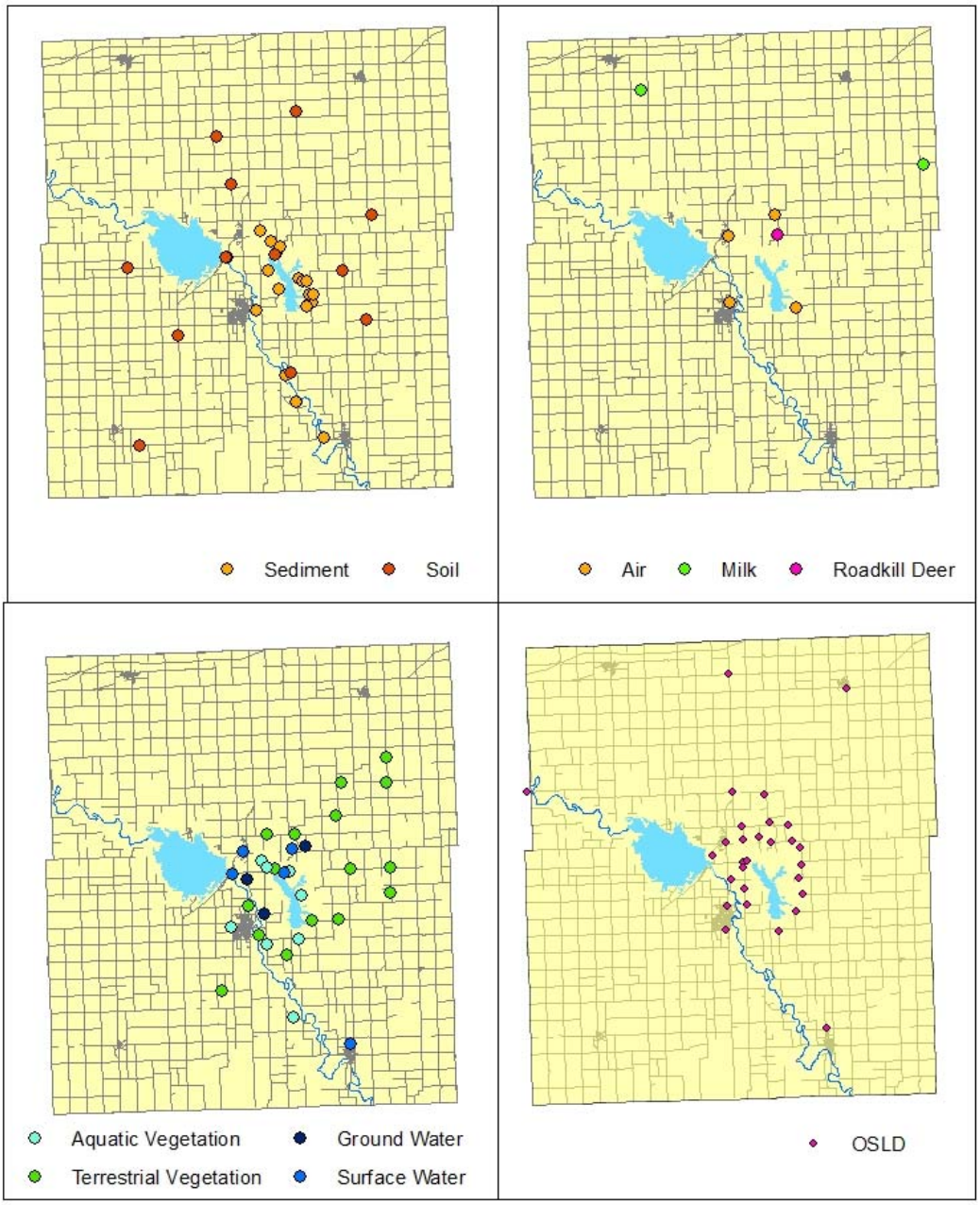
Description	Average	Standard Deviation	Minimum	Maximum	N
OSLD direct radiation, mR per 90 day quarter	17.9	1.8	12.6	21.8	124
Airborne particulate and radioiodine cartridge gamma isotopic analysis (^{7}Be) pCi/m^{3}	0.13	0.05	0.058	0.03	52
Coffey County Lake Surface Water tritium (^{3}H), pCi/l (Spillway)	11811	83.9	10053	15100	12
John Redmond Reservoir, control (N-1) (^{3}H), pCi/l	<350	NA	NA	NA	12
Coffey County Lake MUDS (^{3}H), pCi/l	11673	2297	8840	15635	12
Neosho River Near LeRoy (^{3}H), pCi/l	<350	NA	NA	NA	2
New Strawn City Lake (^{3}H), pCi/l	<350	NA	NA	NA	1
Offsite ground water tritium (^{3}H), pCi/l (All Stations)	<350	NA	NA	NA	23
Onsite ground water tritium (^{3}H), pCi/l (Stations where activity was detected)	2886	2455	786	7265	7
Surface and Ground Water Gamma Isotopic Analysis	Gamma isotopic analysis indicated that no gamma emitters attributable to Wolf Creek Generating Station operation were present above the lower limits of detection in any surface water or ground water sample evaluated.				
Gamma isotopic analysis of soil, pasturage, garden vegetables, and grain.	Gamma isotopic analysis indicated that no gamma emitters attributable to Wolf Creek Generating Station operation were present above the lower limits of detection in any soil, milk, pasturage, garden vegetable and grain sample evaluated.				

Maximum activity attributable to Wolf Creek Generating Station operation, pCi/kg

Coffey County Lake Fish	10421 ± 282 pCi/L ^{3}H

Analysis	Comparison Of KDHE and WCNOC Results Average Ratio of KDHE results to WCNOC results	Comments
OSLD Direct Radiation	1.02, N=48	31 Monitoring Sites
Surface Water ^{3}H	1.06, N=12	CCL Discharge Cove
Sediment gamma isotopic	1.10, N=7	^{137}Cs, when detected
Fish tritium (^{3}H)	1.01, N=3	CCL

Sample Location Maps



Sample Results

Inhalation Pathway

Air Particulate and Iodine

Air samples were collected weekly. Five air-sampling sites, four of which are collocated with WCNOC, have continuously operating low-volume air samplers contained in a fiberglass housing mounted on utility poles approximately one meter from the ground. Air samplers are located at Sharpe, KS (A-1), east of the Coffey County Lake dam (H-1), Burlington, KS (L-1), New Strawn, KS (P-1), and near Westphalia, KS (D-2). The collocated sites include the highest calculated annual average ground level relative concentration (X/Q) area at Sharpe, the highest calculated annual average ground level relative deposition (D/Q) area at New Strawn, and a control location near Westphalia. An average flow rate of 30 liters per minute is used with 47 mm diameter glass fiber particulate filters and 5 percent triethylenediamine (TEDA) impregnated carbon cartridges for radioiodine activity (the major isotope of concern is ^{131}I). TEDA binds the iodine chemically and reduces losses from desorption.

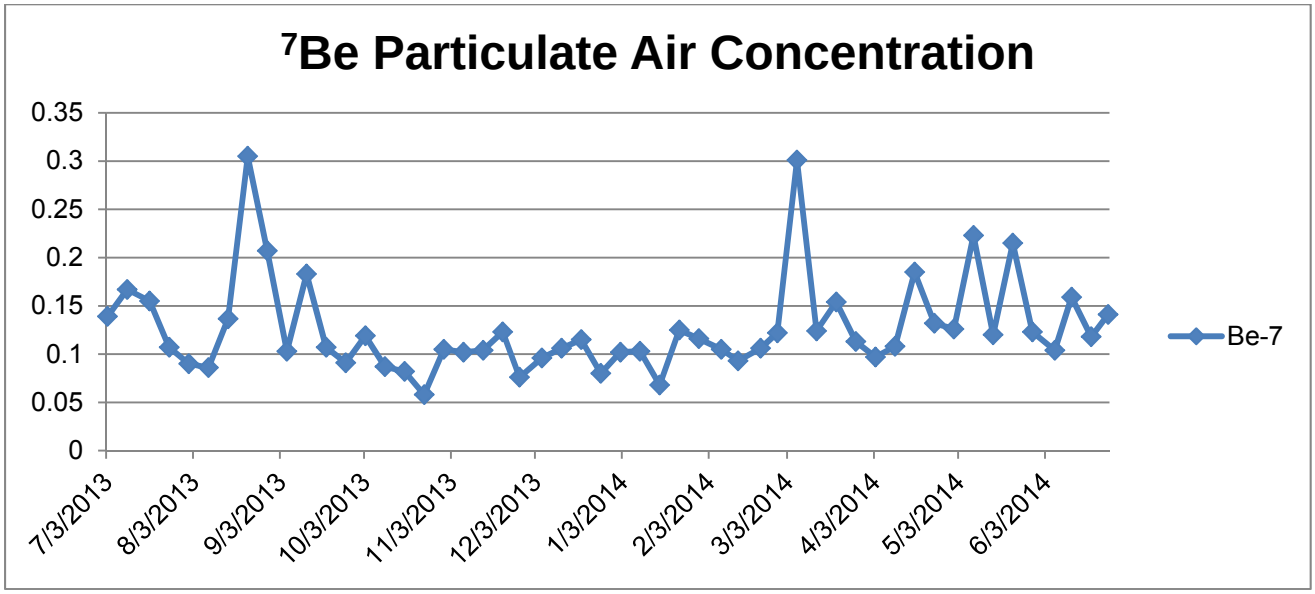
Field assay of each particulate filter was performed at the time of collection. The particulate filter was counted using a thin window GM 'pancake' detector (Ludlum Model 44-40 or equivalent) and a count rate instrument. A sample net count rate of greater than two times the net count rate of the current control (Near Westphalia, D-2) air sample indicates a potential anomaly and the filter is then flagged for individual gamma isotopic analysis.

Gamma isotopic analysis was performed on two composite samples, one composed of the five particulate filters and the other of the five charcoal cartridges. Indication of ^{131}I or any other fission or activation product requires gamma isotopic analysis of each individual particulate filter and associated charcoal cartridge.

Table 1, Weekly air particulate/iodine monitoring, pCi/m^3

Number of Samples	Average ^{7}Be Concentration	Average Iodine Concentration
52	0.13 ± 0.009	<0.033

Graph 1, Weekly Particulate ^{7}Be Concentration, pCi/m^3



Airborne Pathway

Soil

Four indicator, one control, and ten random annual soil samples were collected. Indicator soil samples were collected near Stringtown Cemetery, east of the CCL dam, at the CCL MUDS area, and at the public environmental education area. One control soil sample was collected east of WCGS at the Scott Valley Church. Random soil samples were collected at ten locations within the ten mile zone around WCGS. Soil samples collected from the Coffey County public use areas are split with WCNOC.

A gamma isotopic analysis is performed on all soil samples collected.

Table 2, Annual Samples for Radionuclide Deposition on Soil, pCi/kg KDHE (WCNOC)

Nuclide	A-1 Near Stringtown Cemetery	E-1 Scott Valley Church (control)	H-1 East of CCL Dam
Date	3/10/2014	10/28/2013	4/22/2014
^{137}Cs	<8.0	<8.0	232 ± 9
^{40}K	13300 ± 400	10100 ± 312	14600 ± 418

	P-1 (MUDS)	R-1 (EEA)
Date	5/14/2014	10/28/2013
^{137}Cs	44 ± 3 (50.4 ± 22.6)	<8.0 (249.6 ± 40.4)
^{40}K	11500 ± 754 (10533 ± 702.0)	12500 ± 386 (10747.0 ± 678.9)

Table 3, Random Samples for Radionuclide Deposition on Soil, pCi/kg

Location	Date	Nuclide	
		^{137}Cs	^{40}K
Off 22nd Near Garner Rd.	1/21/2014	190 ± 6	13300 ± 400
Near 8th and Trefoil	11/25/2013	326 ± 11	12500 ± 386
1/4 mi. N of 22nd on Garner Rd	11/27/2013	60 ± 3	10700 ± 323
1/10th mile off of 15th on wayside	3/10/2014	48 ± 8	14700 ± 439
Field near Oxen & 20th Rd	4/9/2014	427 ± 12	13800 ± 396
Field Near 19th and Homestead	4/22/2014	439 ± 13	13300 ± 383
Stringtown Cemetery	5/14/2014	344 ± 9	11800 ± 344
Field Off 10TH RD between Kafir & Juneberry	5/27/2014	201 ± 6	<8732
Field Near 19th and Oxen Rd	6/16/2014	128 ± 8	12700 ± 873
JRR Playground	6/24/2014	242 ± 8	12000 ± 354

Direct Radiation Pathway

Direct Radiation Monitoring

Direct radiation monitoring was accomplished using Landauer Luxel optically stimulated luminescence dosimeters (OSLDs). OSLDs are read by Landauer. OSLD readings are corrected for transit and handling exposure.

Thirty-one locations around the WCGS were monitored by KDHE, including three control locations greater than ten miles from WCGS. Two OSLDs were used per site to generate an average quarterly reading. The dosimeters are contained in specially constructed holders suspended approximately one meter above the ground. Staff members exchange OSLDs quarterly. KDHE has collocated OSLDs with WCNOC at twelve sites.

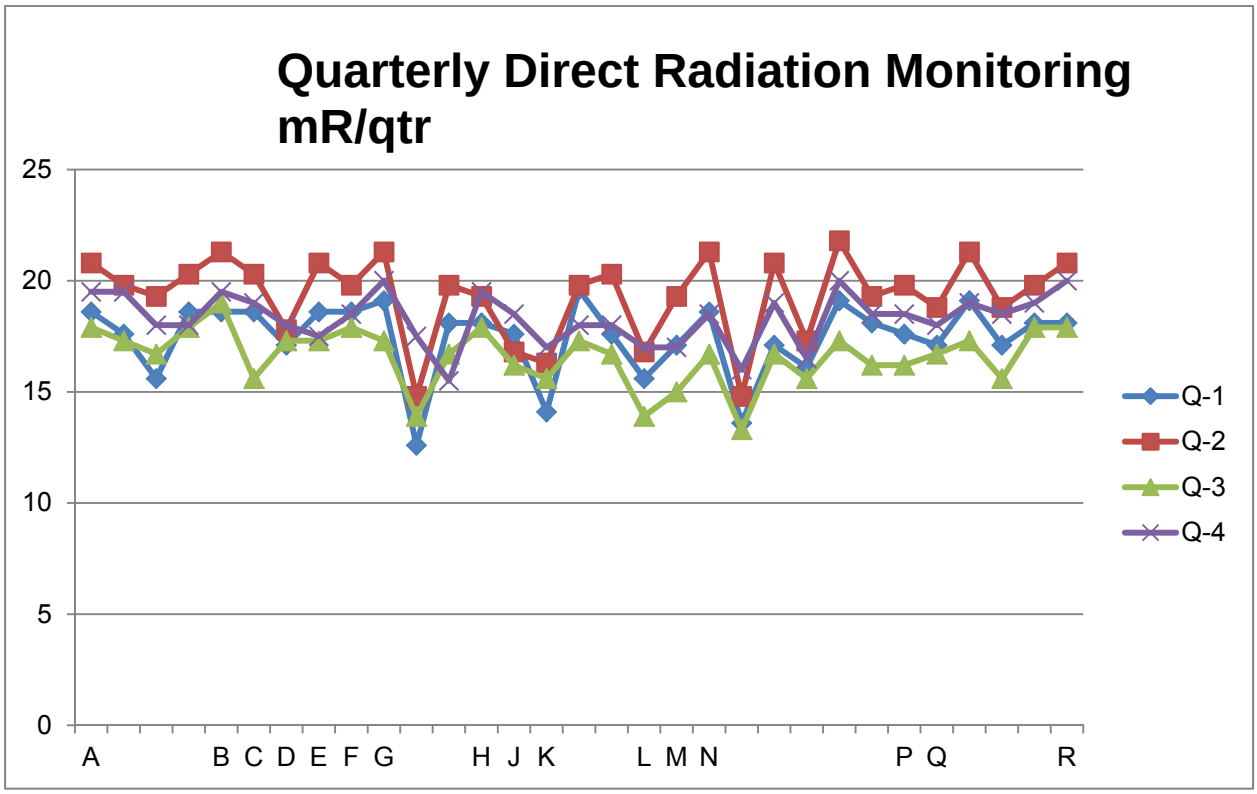
Table 4, Quarterly Direct Radiation Monitoring, mR/Standardized 90-day Qtr.

Location	Quarter 1	Quarter 2	Quarter 3	Quarter 4
1. A-1 (1), North of WCGS	18.6	20.8	17.9	19.5
2. A-2, Sharpe	17.6	19.8	17.3	19.5
3. A-3, Forward Staging Area	15.6	19.3	16.7	18.0
4. B-1, East Sharpe	18.6	20.3	17.9	18.0
5. B-2, Waverly Control	18.6	21.3	19.0	19.5
6. C-1, near residence	18.6	20.3	15.6	19.0
7. D-1 (9), near residence	17.1	17.8	17.3	18.0
8. E-1, near residence	18.6	20.8	17.3	17.5
9. F-1, near residence	18.6	19.8	17.9	18.5
10. G-1 (14), WCNOC gate	19.1	21.3	17.3	20.0
11. H-0 (42), CCL baffle dike A	12.6	14.8	13.9	17.5
12. H-1, east of CCL dam	18.1	19.8	16.7	15.5
13. H-2, LeRoy control	18.1	19.3	17.9	19.5
14. J-1, near residence	17.6	16.8	16.2	18.5
15. K-1 (29), near residence	14.1	16.3	15.6	17.0
16. L-1 (27), near residence	19.6	19.8	17.3	18.0
17. L-2, Burlington	17.6	20.3	16.7	18.0
18. L-3, Coffey County Shop	15.6	16.8	13.9	17.0
19. M-1 (26), near residence	17.1	19.3	15.0	17.0
20. N-1, near pasture	18.6	21.3	16.7	18.5
21. P-0 (43), CCL baffle dike B	13.6	14.8	13.3	16.0
22. P-1, New Strawn	17.1	20.8	16.7	19.0
23. P-2, Hartford Control	16.1	17.3	15.6	16.5
24. P-3, CCL entrance	19.1	21.8	17.3	20.0
25. P-4 (46), CCL near MUDS	18.1	19.3	16.2	18.5
26. P-5, JRR public use area	17.6	19.8	16.2	18.5
27. Q-1, near residence	17.1	18.8	16.7	18.0
28. R-0 (41), Stringtown cemetery	19.1	21.3	17.3	19.0
29. R-1 (37), near residence	17.1	18.8	15.6	18.5
30. R-2 (44), CCL EEA	18.1	19.8	17.9	19.0
31. R-3, near Coffey County Airport	18.1	20.8	17.9	20.0

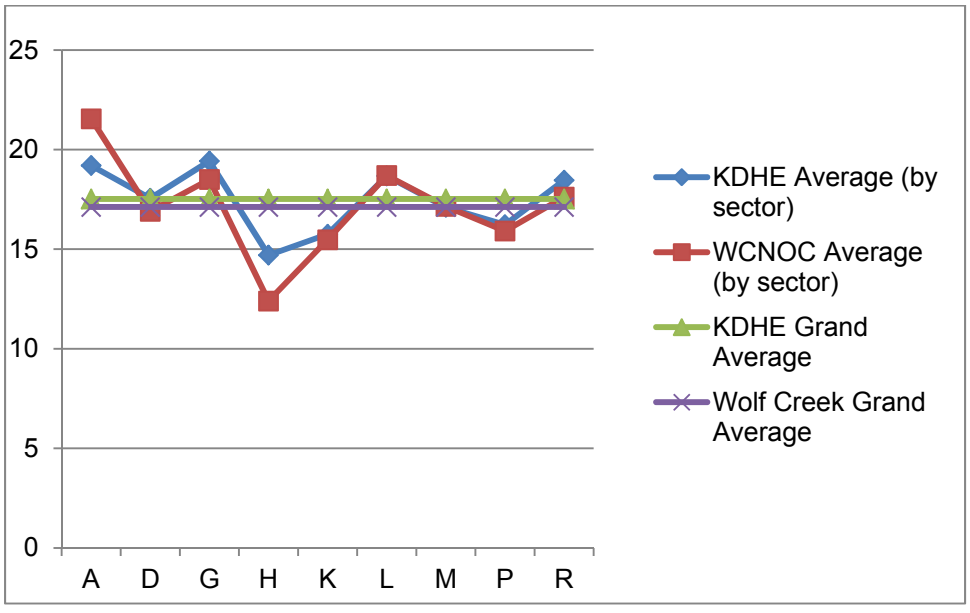
Table 5, Quarterly Collocated Direct Radiation Monitoring, mR/Standardized 90-day Qtr.

Location KDHE(WCNOC)	KDHE Monitoring Period	KDHE	WCNOC
1. A-1 (1)	7/11/2013-10/4/2013	18.6	21.5
	10/4/2013-1/13/2014	20.8	21.8
	1/13/2014-4/2/2014	17.9	19.2
	4/2/2014-7/1/2014	19.5	23.7
2. D-1 (9)	7/11/2013-10/4/2013	17.1	15.9
	10/4/2013-1/13/2014	17.8	17.3
	1/13/2014-4/2/2014	17.3	17.4
	4/2/2014-7/1/2014	18.0	17.0
3. G-1 (14)	7/11/2013-10/4/2013	19.1	18.0
	10/4/2013-1/13/2014	21.3	17.8
	1/13/2014-4/2/2014	17.3	20.0
	4/2/2014-7/1/2014	20.0	18.2
4. H-0 (42)	7/11/2013-10/4/2013	12.6	12.4
	10/4/2013-1/13/2014	14.8	12.8
	1/13/2014-4/2/2014	13.9	12.9
	4/2/2014-7/1/2014	17.5	11.5
5. K-1 (29)	7/11/2013-10/4/2013	14.1	14.3
	10/4/2013-1/13/2014	16.3	16.1
	1/13/2014-4/2/2014	15.6	16.2
	4/2/2014-7/1/2014	17.0	15.3
6. L-1 (27)	7/11/2013-10/4/2013	19.6	20.7
	10/4/2013-1/13/2014	19.8	17.7
	1/13/2014-4/2/2014	17.3	17.9
	4/2/2014-7/1/2014	18.0	18.5
7. M-1 (26)	7/11/2013-10/4/2013	17.1	16.8
	10/4/2013-1/13/2014	19.3	19.5
	1/13/2014-4/2/2014	15.0	15.7
	4/2/2014-7/1/2014	17.0	16.6
8. P-0 (43)	7/11/2013-10/4/2013	13.6	12.3
	10/4/2013-1/13/2014	14.8	12.5
	1/13/2014-4/2/2014	13.3	12.3
	4/2/2014-7/1/2014	16.0	13.3
9. P-4 (46)	7/11/2013-10/4/2013	18.1	18.9
	10/4/2013-1/13/2014	19.3	20.6
	1/13/2014-4/2/2014	16.2	18.4
	4/2/2014-7/1/2014	18.5	19.0
10. R-0 (41)	7/11/2013-10/4/2013	19.1	19.4
	10/4/2013-1/13/2014	21.3	18.3
	1/13/2014-4/2/2014	17.3	17.8
	4/2/2014-7/1/2014	19.0	16.3
11. R-1 (37)	7/11/2013-10/4/2013	17.1	15.3
	10/4/2013-1/13/2014	18.8	18.8
	1/13/2014-4/2/2014	15.6	15.0
	4/2/2014-7/1/2014	18.5	13.7
12. R-2 (44)	7/11/2013-10/4/2013	18.1	18.5
	10/4/2013-1/13/2014	19.8	20.6
	1/13/2014-4/2/2014	17.9	19.2
	4/2/2014-7/1/2014	19.0	18.5

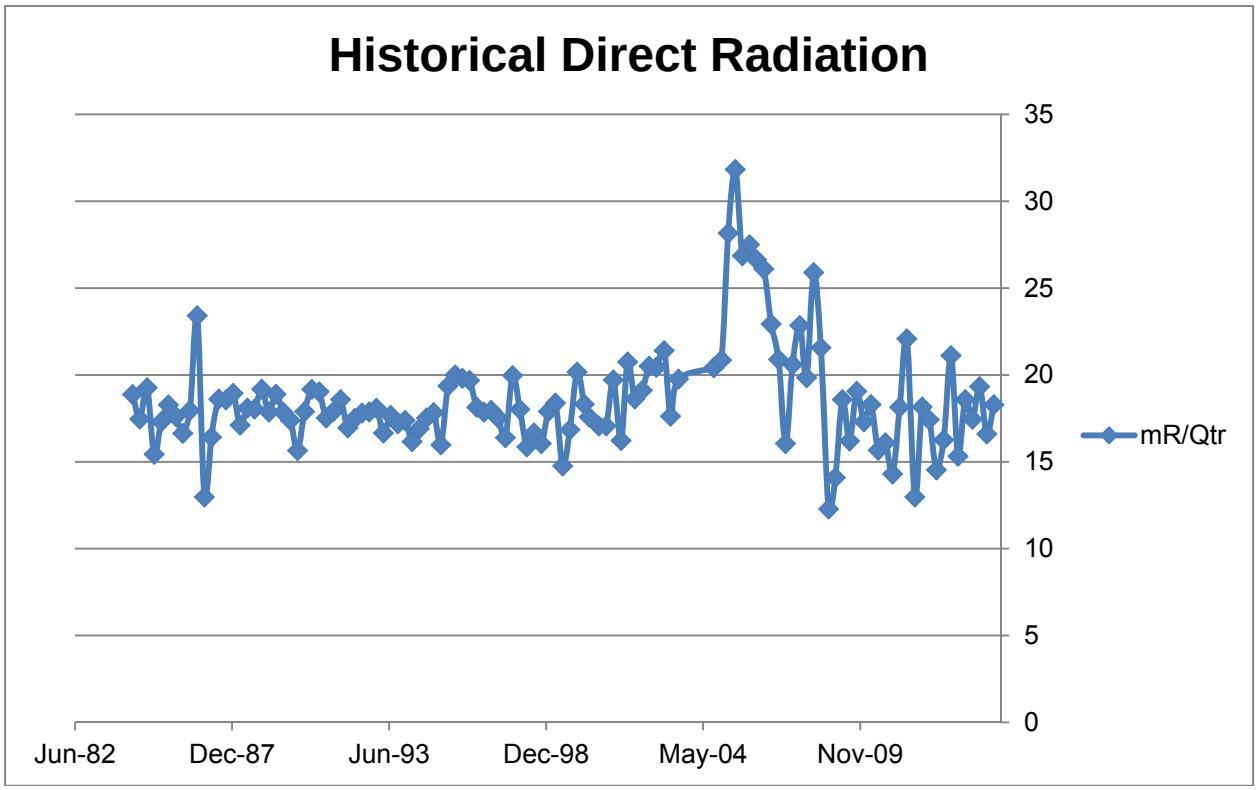
Graph 2, Quarterly direct radiation results for KDHE OSLD sites



Graph 3 Direct radiation monitoring results for co-located OSLD sites (mR/Quarter)



Graph 4 Historical KDHE direct radiation monitoring results (mR/Qtr)



Waterborne Pathway

Surface Water

Surface water sampling was accomplished through the collection of one-gallon grab samples at the indicated locations. A control sample was collected monthly from John Redmond Reservoir. One sample was collected monthly from the Coffey County Lake (CCL) at the spillway. One sample was collected monthly at the public fishing area on CCL, near the Makeup Discharge Structure (MUDS). Samples were collected monthly from the Neosho River near Leroy only when Coffey County Lake was overflowing to Wolf Creek at the spillway. Discharges to the river occurred during August 2013 and June of 2014. A sample was also collected annually from the New Strawn City Lake.

A gamma isotopic and tritium (^{3}H) analysis was done on each CCL water sample and ^{3}H analysis was done quarterly on a composite sample from JRR. Samples from John Redmond Reservoir and the Coffey County Lake Spillway were split with WCNOC.

Table 6 Monthly samples for waterborne radionuclides (^{3}H) in surface water, pCi/L

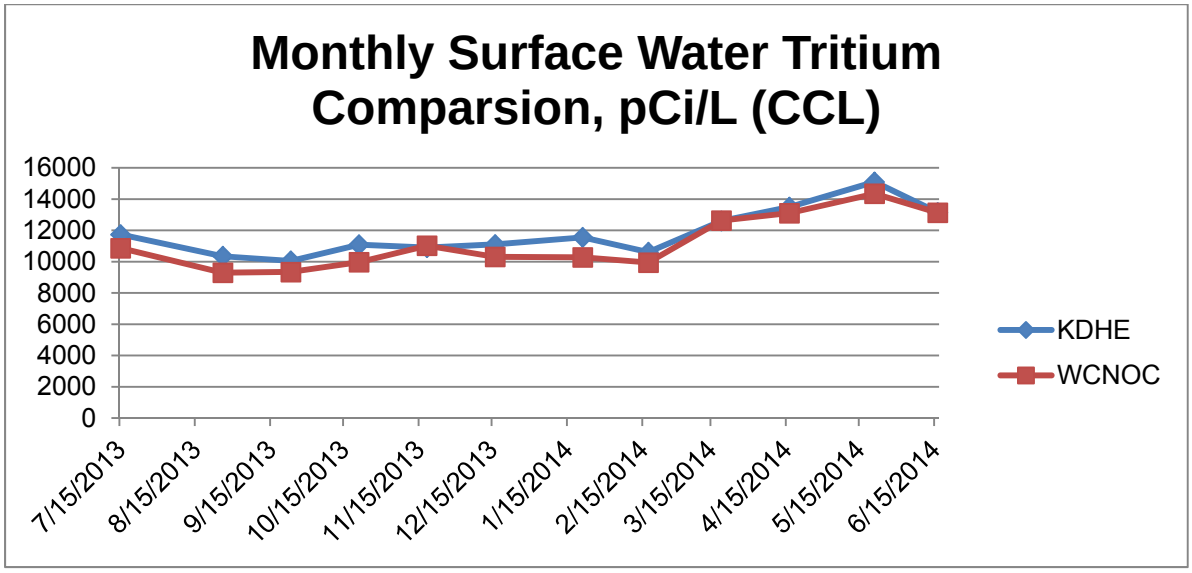
CCL Spillway			John Redmond Reservoir (Control)			MUDS	
Date	KDHE	WCNOC	Date	KDHE	WCNOC	Date	KDHE
7/15/2013	11732 ± 329	10867 ± 309	7/15/2013	<350	<159	7/15/2013	11130 ± 322
8/26/2013	10349 ± 589	9295 ± 280	8/26/2013	<350	<149	8/13/2013	8876 ± 290
9/23/2013	10053 ± 311	9340 ± 282	9/23/2013	<350	<146	9/12/2013	9918 ± 310
10/21/2013	11085 ± 321	9970 ± 293	10/21/2013	<350	<148	10/21/2013	10747 ± 317
11/18/2013	10900 ± 300	11024 ± 309	11/18/2013	<350	<149	11/14/2013	8840 ± 300
12/16/2013	11100 ± 300	10309 ± 296	12/16/2013	<350	<145	12/19/2013	10700 ± 300
1/21/2014	11554 ± 444	10278 ± 297	1/21/2014	<350	<151	1/13/2014	11010 ± 428
2/24/2014	10355 ± 319	9944 ± 288	2/17/2014	<350	<147	2/17/2014	10610 ± 316
3/19/2014	12606 ± 326	12629 ± 327	3/19/2014	<350	<145	3/19/2014	15635 ± 357
4/16/2014	13493 ± 337	13104 ± 334	4/16/2014	<350	<144	4/22/2014	14357 ± 347
5/21/2104	15100 ± 400	14318 ± 347	5/21/2104	<350	<147	5/14/2014	14625 ± 352
6/16/2014	13147 ± 333	13130 ± 334	6/16/2014	<350	<141	6/10/2014	13626 ± 349

H-1 Neosho River Near Leroy	
Date	KDHE
8/6/2013	<350
6/10/2014	<350

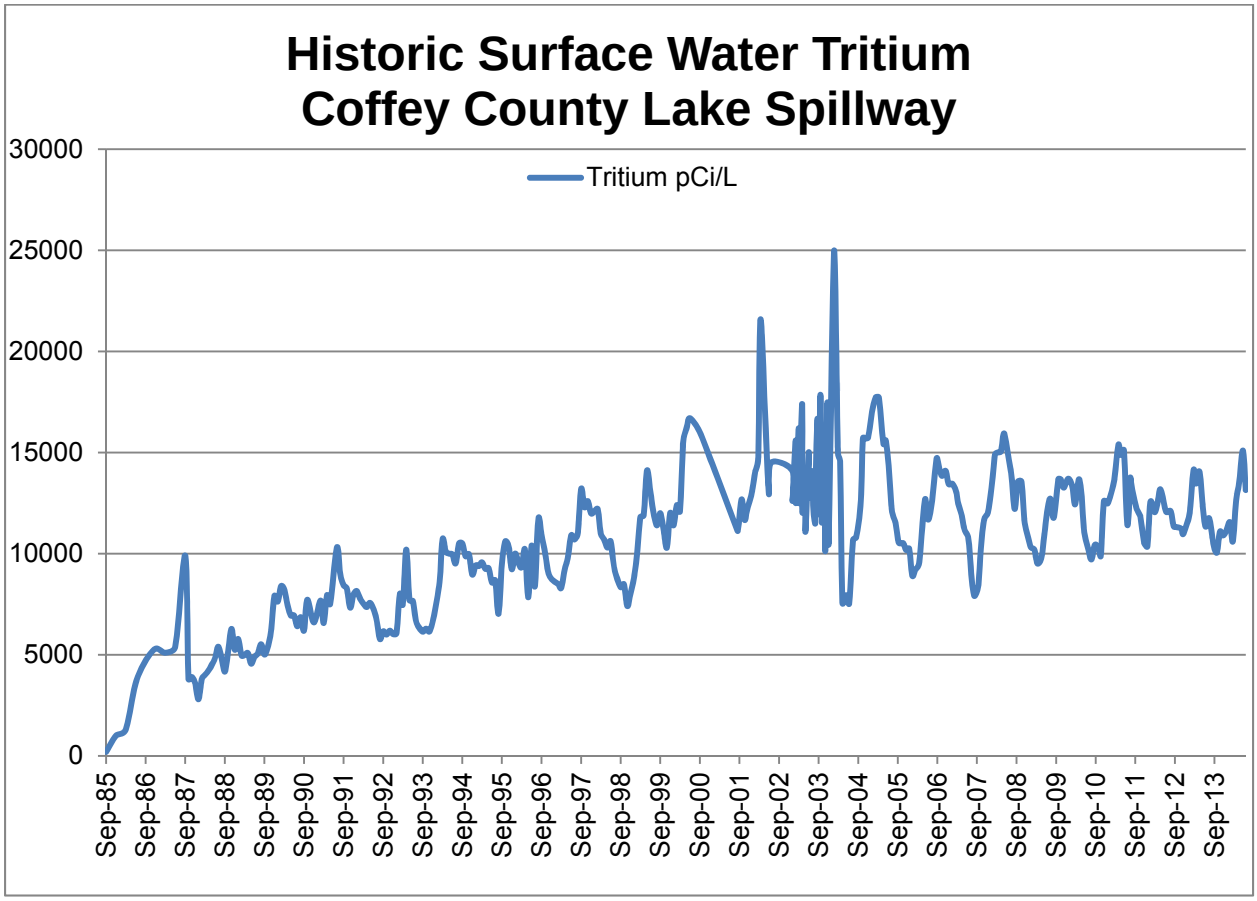
Table 7 Annual samples for deposition of airborne radionuclides in surface water, pCi/L

New Strawn City Lake	
Date	^{3}H
6/10/2014	<350

Graph 5 Comparison of CCL Spillway monthly surface water tritium results (pCi/L)



Graph 6 Historical KDHE surface water tritium results (CCL Spillway)



Ground Water

Ground water was collected quarterly offsite at wells in sectors B (control), C, F, G, and J. The control sample location was hydrologically up gradient from the facility and the other five are hydrologically down gradient. Sample point in sector G was not available for two quarters. Samples were split with WCNOC. Samples were collected within the Wolf Creek owner controlled area along the Essential Service Water-buried pipe (two locations) and in the Wolf Creek protected area near the Auxiliary Building. Wolf Creek provided only the East ESW-W sample in the third quarter. Because of the dry conditions they were unable to collect a sample at the Auxiliary Building and West ESW-W during the third quarter.

Gross alpha, beta, tritium and gamma isotopic analysis are done on each sample.

Table 8 Quarterly samples for waterborne radionuclides in ground water, pCi/L

Offsite Ground Water

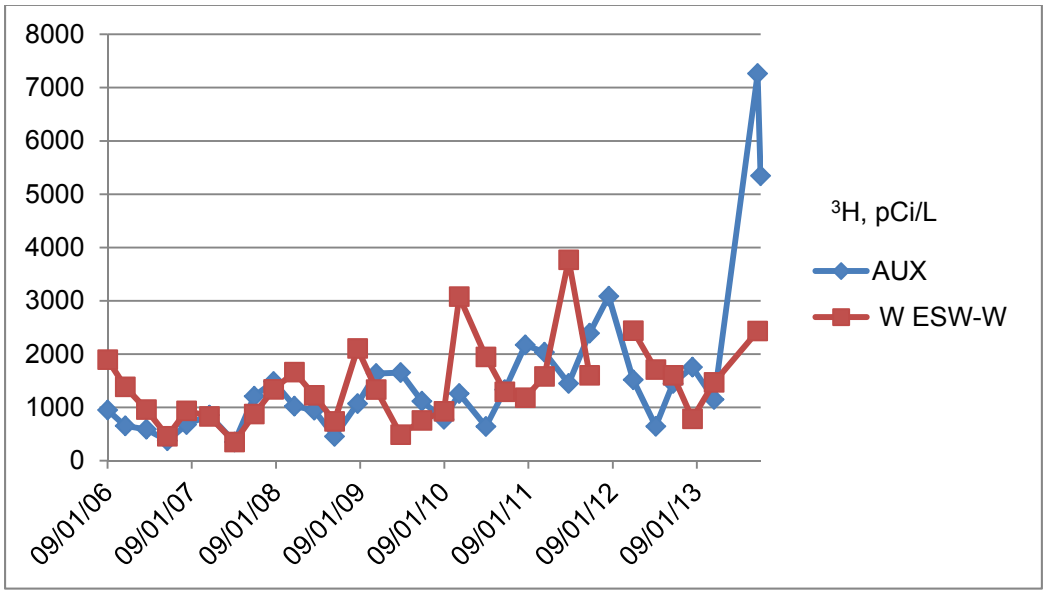
B-1 (B-12)			G-1 (G-2)		
Date	^{3}H KDHE	^{3}H WCNOC	Date	^{3}H KDHE	^{3}H WCNOC
8/26/2013	<350	<149	8/26/2013	<350	<149
11/18/2013	<350	<149	11/18/2013	<350	<149
2/17/2014	<350	<147			
5/21/2014	<350	<145			
F-1 (F-1)			**C-2 (C-49)**		
Date	^{3}H KDHE	^{3}H WCNOC	Date	^{3}H KDHE	^{3}H WCNOC
8/26/2013	<350	<149	8/26/2013	<350	<149
11/18/2013	<350	<149	11/18/2013	<350	<149
2/24/2014	<350	<138	2/17/2014	<350	<147
5/21/2014	<350	<145	5/21/2014	<350	<145
J-1 (J-2)			**C-1 (C-10)**		
Date	^{3}H KDHE	^{3}H WCNOC	Date	^{3}H KDHE	^{3}H WCNOC
8/26/2013	<350	<149	8/26/2013	<350	<149
11/18/2013	<350	<149	11/25/2013	<350	<155
2/17/2014	<350	<147	2/17/2014	<350	<147
5/21/2014	<350	<145	5/21/2014	<350	<145

Onsite Ground Water

Auxiliary Building			EAST ESW-W		
Date	^{3}H KDHE	^{3}H WCNOC	Date	^{3}H KDHE	^{3}H WCNOC
8/13/2013	1754 ± 173	1681 ± 146	8/12/2013	<350	294 ± 107
11/14/2013	1150 ± 180	989 ± 117	11/14/2013	<350	<149
5/22/2014	7265 ± 269	6758 ± 245	2/20/2014	<350	<143
6/4/2014	5347 ± 248	5107 ± 223	5/21/2014	<350	<148

WEST ESW-W		
Date	^{3}H KDHE	^{3}H WCNOC
8/12/2013	786 ± 154	804 ± 123
11/14/2013	1470 ± 180	1358 ± 129
5/21/2014	2433 ± 206	1836 ± 142

Graph 7 Historic Owner Controlled Area (Onsite) Groundwater Tritium, pCi/L



Shoreline and Bottom Sediments

Shoreline sediment and bottom sediment were collected in the environment surrounding WCGS. Indicator bottom sediment samples were collected in the Coffey County Lake discharge cove, public environmental education area, and the CCL MUDS public access fishing area. A control sample of bottom sediment was obtained from John Redmond Reservoir. Indicator shoreline sediment was collected at the CCL discharge cove, the CCL MUDS public access fishing area, Wolf Creek below the CCL dam, and Stringtown Cemetery. A control sample of shoreline sediment was collected at JRR. Nine random bottom sediments were collected on CCL. Seven random shoreline sediments were collected on CCL and the Neosho River. The CCL and JRR samples are split with WCNOC.

A gamma isotopic analysis is done on all sediment samples collected.

Table 9 Annual samples for waterborne radionuclides in sediments, pCi/kg dry

Location	Type	Date	^{137}Cs KDHE (WCNOC)	^{60}Co KDHE (WCNOC)	^{40}K KDHE (WCNOC)
Wolf Creek	Shoreline	8/13/2013	25 ± 2	<11	12200 ± 400
EEA	Bottom	8/26/2013	86 ± 4 (67.0 ± 29.5)	<11 (<12.2)	15200 ± 500 (11346.0 ± 669.6)
EEA	Shoreline	9/3/2013	94 ± 4 (89.2 ± 41.6)	<11 (<9.6)	14700 ± 400 (11893.0 ± 681.3)
MUDS	Bottom	9/16/2013	30 ± 2 (38.4 ± 22.6)	<11 (<9.8)	13100 ± 400 (10357 ± 645.8)
CCL Discharge Cove	Bottom	12/3/2013	86 ± 8 (89.5 ± 52.9)	<11 (<29.2)	19800 ± 828 (9402.3 ± 944.4)
JRR	Bottom	12/3/2013	150 ± 6 (84.8 ± 43.3)	<11 (<13.3)	18900 ± 570 (11660.0 ± 993.4)
CCL Discharge Cove	Shoreline	12/3/2013	<8 (<17.7)	<11 (<12.2)	7160 ± 22 (6367.6 ± 442)
JRR	Shoreline	12/3/2013	<8 (<23.5)	<11 (<10.9)	12800 ± (10926.0 ± 595.2)
Stringtown Cemetery	Bottom	5/14/2014	31 ± 2 (<22.1)	<11 (<12.2)	14000 ± 402 (11340.0 ± 732.6)
CCL Discharge Cove	Bottom	6/23/2014	141 ± 6 (130.4 ± 43.7)	<11 (<19.3)	16700 ± 490 (13910.0 ± 827.8)
CCL Discharge Cove	Shoreline	6/23/2014	11 ± 2 (<22.5)	<11 (<14.0)	7990 ± 238 (5731.5 ± 471)
JRR	Bottom	6/24/2014	112 ± 8 (132.3 ± 43.0)	<11 (<13.1)	21400 ± 623 (16906.0 ± 901.7)
JRR	Shoreline	6/24/2014	<8 (<24.1)	<11 (<9.4)	7810 ± 1510 (11494.0 ± 789.4)

Table 10 Random samples for waterborne radionuclides in sediments, pCi/kg dry

Date	Location	Type	^{60}Co	^{137}Cs
7/23/2013	Neosho River at Burlington Fairgrounds	Shoreline	<11	34 ± 2
9/10/2013	CCL East of Dam	Shoreline	<11	11 ± 1
10/7/2013	N End CCL	Bottom	<11	12 ± 2
10/7/2013	N End CCL	Bottom	<11	15 ± 2
10/7/2013	N End CCL	Bottom	<11	43 ± 3
10/7/2013	N End CCL	Bottom	<11	<8.0
10/7/2013	N End CCL	Bottom	<11	11 ± 2
12/2/2013	Near Neosho River bridge in LeRoy	Shoreline	<11	<8
12/2/2013	Neosho River between 6th RD and 7th RD	Shoreline	<11	<8
4/9/2014	Near Bridge to Burlington	Shoreline	<11	<8
5/14/2014	EEA Bird Blind	Shoreline	<11	<8
5/30/2014	E Side CCL	Bottom	<11	15 ± 8
5/30/2014	SE CCL	Bottom	<11	11 ± 8
5/30/2014	NW CCL	Bottom	<11	<8
5/30/2014	W Side CCL	Bottom	<11	<8
6/3/2014	Black Bear Bosin Behind EOF	Shoreline	<11	<8

Aquatic Vegetation and Algae

Annual aquatic vegetation (algae and/or rooted) indicator samples were collected from the Coffey County Lake and Wolf Creek below the Coffey County Lake dam. Control samples of aquatic vegetation were obtained at John Redmond Reservoir. The Coffey County Lake samples are split with WCNOC.

Gamma isotopic analysis is performed on all aquatic vegetation samples.

Table 11 Annual samples for waterborne radionuclides in aquatic vegetation KDHE,pCi/kg (dry) (WCNOC), pCi/kg (wet)

Location	Sample Type	Date	^{40}K	^{7}Be
JRR above dam	Algae	7/15/2013	10700 ± 362	1560 ± 79.4
CCL DC	Lotus	8/1/2013	15300 ± 721 (2282.7 ± 388.3)	5840 ± 319 (1872.6 ± 269.9)
Wolf Creek	Arrowhead	8/13/2013	24000 ± 807	1800 ± 124
CCL EEA	Arrowhead	9/3/2013	43800 ± 1340 (4998.3 ± 424.1)	578 ± 120 (<146.7)
CCL MUDS	Pondweed	9/16/2013	8070 ± 363 (1861 ± 164.7)	1070 ± 85 (299.4 ± 67.4)
CCL DC (Alternate)	American Pondweed	6/23/2014	16900 ± 670 (2517.9 ± 298.3)	1600 ± 132 (<133.6)

Table 12 Random samples for waterborne radionuclides in aquatic vegetation KDHE, pCi/kg

Location	Sample Type	Date	^{40}K	^{7}Be
Ditch Near 14th and Garner Rd	Water Willow	7/23/2013	16400 ± 602	3100 ± 170
Trefoil RD Between 18th and 19th	Calamus	7/25/2013	26800 ± 992	2380 ± 207
Neosho River at Spillway	Bulrush	7/23/2013	14870 ± 795	815 ± 174
Flooded Area of JRR by 16th RD	Duckweed	8/12/2013	11700 ± 817	7210 ± 675
CCL Boat Ramps	Algae	6/3/2014	23800 ± 152	4020 ± 178
17th and Shetland	Cattails	6/24/2014	1850 ± 65	<360

Ingestion Pathway

Milk

Milk was sampled quarterly in Coffey County at two locations. Indicator samples were obtained from the Sunrise Dairy near Westphalia, KS. Control samples were obtained from Linsey Dairy near Lebo, KS. Each milk sample is analyzed for low levels of radioiodine and other gamma emitting nuclides. No gamma emitting nuclides attributable to Wolf Creek operation were detected in any milk sample.

Table 13 Quarterly samples for radionuclides in milk, pCi/L

Linsey Dairy			Sunrise Dairy		
Date	^{131}I	^{40}K	Date	^{131}I	^{40}K
8/15/2013	<1	1500 ± 55	09/10/13	<1	1330 ± 55
11/25/2013	<1	1480 ± 52	12/19/2014	<1	1490 ± 51
3/20/2014	<1	1440 ± 50	03/10/14	<1	<1300
5/15/2014	<1	<1300	06/03/14	<1	1440 ± 49

Fish/Game Animals/Domestic Meat

Fish samples were collected from the Coffey County Lake and below John Redmond Reservoir on the Neosho River. Sample portions from fish collected in the Coffey County Lake and below John Redmond Reservoir on the Neosho River were split with WCNOC. Fish collected at John Redmond Reservoir are used for control samples. Twenty fish from a total of nine species were sampled.
Game animal sampling is usually limited to the collection of edible meat portions from road-killed deer. Sample portions of road-killed deer are usually collected as available by WCNOC and split with KDHE for laboratory analysis. One deer sample was obtained during SFY 2014.

A gamma isotopic analysis is done on all samples collected. Sample portions were edible. Tritium analysis is done on at least one species of fish from each location sampled.

Table 14 Annual samples for radionuclides in fish pCi/kg, wet)

Location	Date	Type	^{3}H KDHE (WCNOC)	Gamma Activity
CCL	10/17/2013	Common Carp	NA (7348 ± 223)	No Gamma Activity Above MDA was Detected in any Fish Sample
		Walleye	7774 ± 278 (7414 ± 228)	
		Blue Catfish	NA (7004 ± 228)	
		Small Mouth Buffalo	NA (6985 ± 220)	
		White Bass	NA (7496 ± 227)	
		Channel Catfish	NA (8007 ± 242)	
JRR	12/3/2013	Common Carp	NA (<118)	
		Freshwater Drum	<1200 (<122)	
		Channel Catfish	NA (<113)	
CCL	5/22/2014	River Carpsucker	NA (9191 ± 231)	
		White Bass	10421 ± 282 (10468 ± 274)	
		Smallmouth Buffalo	9962 ± 278 (10073 ± 258)	
		Channel Catfish	NA (10336 ± 265)	
		Smallmouth Bass	NA (9653 ± 256)	
		Common Carp	NA (9512 ± 250)	
		Freshwater Drum	NA (10500 ± 326)	
JRR	6/24/2014	Common Carp	NA (<106)	
		Flathead Catfish	<1200 (<104)	
		Bigmouth Buffalo	NA (<95)	
		Smallmouth Buffalo	<1200 (<105)	

Table 15 Random samples for radionuclides in game, pCi/kg

Sample Location	Date	Sample Type	^{40}K KDHE (WCNOC)
Sector R, 2.7 Miles from Wolf Creek	11/18/2013	Roadkill Deer	3530 ± 113 (3070.6 ± 355.7)

Terrestrial Vegetation and Food Products

Terrestrial vegetation samples were taken at various locations around WCGS. This includes samples of crops grown throughout Coffey County, broadleaf vegetation taken from gardens near the WCGS boundary, and pasturage near WCGS. Samples collected on WCNOC property and samples of crops were split with WCNOC. A control sample was collected at Scott Valley Church approximately 6 miles from WCGS. Ten random samples were collected from locations around WCGS within the 50 mile zone.

A gamma isotopic analysis was done on each vegetation sample and edible portions of food products collected.

Table 16 Annual Samples for Terrestrial Vegetation and Food Products, pCi/kg

Sample ID	Location	Sample Type	Date	^{40}K KDHE (WCNOC)	^{7}Be KDHE (WCNOC)
WCFV-1-A-005-2.5	Sharpe	Corn on Cob	10/3/2013	2240 ± 86	<360
NR-U1	Sector K, 4.5 mi. SSW of Wolf Creek	Irrigated Corn	10/10/2013	2970 ± 95 (2543.7 ± 201.9)	<360 (<57.4)
NR-D2	Kerry Trostle Farm	Irrigated Soybeans	10/14/2013	18800 ± 549 (12882 ± 496.4)	<360 (<60.2)
WCFV-1-E-087-5.8	Scott Valley Church (Control)	Pasturage	10/21/2013	16300 ± 28	<360
NR-D1	Coffey County	Non-Irrigated Soybeans	10/29/2013	12700 ± 375 (16342.0 ± 514.3)	<360 (<65.4)
NR-U1	Sector K, 4.5 mi. SSW of Wolf Creek	Non-Irrigated Soybeans	11/4/2013	13200 ± 386 (12669.0 ± 487.5)	<360 (<57.1)
WCFV-3-P-289-1.6	MUDS	Pasturage	5/27/2014	19900 ± 648 (4423.9 ± 653.5)	5190 ± 205 (1546.2 ± 253.3)
WCFV-1-H-157-3.1	East of Dam	Horseradish Greens	5/27/2014	41500 ± 2770	3050 ± 212
WCFV-1-R-330-2.9	EEA	Pasturage	6/3/2014	21500 ± 963 (7351.1 ± 368.1)	<360 (1022.1 ± 140.8)

Table 17, Random Samples for Vegetation and Food Products, pCi/kg

Location	Sample Type	Date	^{40}K	^{7}Be
Field Near 8th LN and Emmer RD	Wheat	7/1/2013	3450 ± 99.4	<360
13th LN and Lynx RD	Wheat	7/1/2013	4380 ± 177	1020 ± 54.6
Near 14th RD and Fauna RD	Red Milo	9/10/2013	3250 ± 11	438 ± 26
207 Cheyenne New Strawn	Tomatoes	9/10/2013	261 ± 88	<360
Across from JRR Project Office	Apples	9/16/2013	1060 ± 40	<360
Field Near 17th RD and Milo RD	Sunflower W/Seeds	10/7/2013	21100 ± 46	<360
On Underwood Between 14th RD and 15th RD	Corn on Cob	10/28/2013	3220 ± 104	<360
Field near 10th RD and Planter Rd.	Corn	10/28/2013	2320 ± 76	<360
Field Near 23rd RD and Wayside RD	Red Milo	11/14/2013	6100 ± 229	1080 ± 58
Field Near 11th RD and Shetland RD	Soybeans	11/21/2013	13900 ± 407	<360

KDHE Radiochemistry Laboratory

Quality Assurance

The KDHE Radiation Laboratory has an established internal Quality Assurance program. Quality Control elements include routine calibrations and performance checks on counting equipment and participation in an environmental radioactivity laboratory intercomparison studies program. This program is currently accomplished with blind samples purchased from Environmental Resource Associates. Results for SFY 2014 are presented in Table 18.

Equipment

The following is a description of the equipment used by the KHEL Radiochemistry laboratory.

Multichannel gamma-spectrometer
Gamma radiation is measured spectra determined with a Canberra Genie-2000 Multichannel Analyzer (MCA) system. Detectors available are three high purity germanium detectors (efficiencies – 20 % - 40%) and one germanium-lithium (GeLi) Detector (efficiency 20%).

Low background alpha/beta system

Low background alpha/beta gas-flow internal proportional counters – one Tennelec LB5100, one Oxford Series 5XLB, one Tennelec LB4000 multi-detector and one Canberra 2201.

Internal proportional counter (IPC)

Gross alpha and radium analyses are performed with windowless gas-flow internal proportional counters – four Protean MPC 2000 and two NMC PC5.

Liquid scintillation

Analysis for tritium in water is performed using a one Wallac 1409 and one PE Tri-Carb 3100 TR.

Miscellaneous equipment

The Radiochemistry Section has various devices used for special purposes. A Ludlum Model 2200 single channel analyzer is used with a radon flask scintillation counter for radon and radium analyses. Another Ludlum Model 2200 single channel analyzer is used with a halogen quenched GM pancake probe for routine monitoring of personnel and incoming samples.

Table 18 KDHE Radiochemistry Laboratory ERA Intercomparison Studies

[1] The KDHE radiochemistry laboratory, under certification of the Environmental Protection Agency is required to pass one PT study for certified analytes per year, and participates in extra PT studies throughout the year as additional Quality Assurance checks.

Analyte	Analysis Date	Units	Reported Value	Assigned Value	Acceptance Limits	Performance Evaluation
Barium-133	7/10/2013	pCi/L	69.9	74.5	62.4 - 82.0	Acceptable
	10/11/2013	pCi/L	43.4	54.2	44.7 - 59.9	Not Acceptable
Cesium-134	7/10/2013	pCi/L	67.4	72.4	59.1 - 79.6	Acceptable
	10/11/2013	pCi/L	74.1	86.7	71.1 - 95.4	Acceptable
Cesium-137	7/10/2013	pCi/L	156	155	140 - 172	Acceptable
	10/11/2013	pCi/L	197	206	185 - 228	Acceptable
Cobalt-60	7/10/2013	pCi/L	83.8	82.3	74.1 - 92.9	Acceptable
	10/11/2013	pCi/L	98.4	102	91.8 - 114	Acceptable
Gross Alpha	7/25/2013	pCi/L	48.8	57.1	29.8 - 71.2	Acceptable
Gross Beta	7/18/2013	pCi/L	38.9	41.8	27.9 - 49.2	Acceptable
Tritium	10/27/2013	pCi/L	17700	17700	15500 - 19500	Acceptable
Iodine-131	7/10/2013	pCi/L	24.3	24.3	20.2 - 28.8	Acceptable
Strontium-89	7/18/2013	pCi/L	31.7	36.5	27.4 - 43.4	Acceptable
Strontium-90	8/1/2013	pCi/L	22.1	19.8	14.1 - 23.4	Acceptable
Zinc-65	10/11/2013	pCi/L	343	333	300 - 389	Acceptable

[1] The KDHE radiochemistry laboratory, under certification of the Environmental Protection Agency is required to pass one PT study for certified analytes per year, and participates in extra PT studies throughout the year as additional Quality Assurance checks.

Table 19 Method Detection Limits

GeLi [HPGe] detection system [a]						
Environmental Sampling						
	Water and Milk	Filter	Wipe	Soil and Sediment	Biota	Vegetation and Food Products
Minimum sample size	2000 ml	1500 m^3	Total	0.45 kg	0.3 kg	1 kg
Minimum Counting Time	8 hr.	3 hr	3 hr.	15 hr.	15 hr.`	15 hr.
Method Detection Limit	pCi/L	pCi/m^3	pCi/wipe	pCi/kg-dry	pCi/kg-wet	pCi/kg-dry
^{7}Be	64[22]	0.03 [0.02]	N/A	346 [186]	231 [144]	35[19]
^{40}K	88 [39]	0.03 [0.02]	N/A	828 [654]	459 [262]	360 [72]
^{51}Cr	52 [32]	0.01 [0.009]	5 [3]	35 [22]	41 [32]	55 [46]
^{54}Mn	4 [2]	0.004 [0.003]	1 [0.7]	7 [11]	30 [15]	51 [24]
^{58}Co	4 [2]	0.008 [0.002]	2 [1]	11 [23]	37 [20]	60 [36]
^{59}Fe	8 [3]	0.01 [0.01]	3 [2]	22 [16]	41 [15]	107 [52]
^{60}Co	11 [7]	0.01 [0.0053]	2.5 [1.7]	11 [35]	43 [26]	56 [50]
^{65}Zn	8 [4]	0.01 [0.007]	N/A	48 [30]	38 [22]	125 [63]
^{95}Nb	7 [3]	0.009 [0.007]	2.5 [1.4]	13 [30]	44 [26]	48 [4]
^{95}Zr	6 [3]	0.01 [0.002]	0.5 [0.3]	20 [27]	27 [19]	86 [54]
^{99}Mo	5 [3]	0.002 [0.0014]	1 [0.6]	83 [43]	33 [21]	****
^{103}Ru	10 [7]	0.004 [0.003]	N/A	10 [20]	29 [21]	44 [47]
^{106}Ru	55 [43]	0.07 [0.05]	1.5 [1]	100 [192]	43 [29]	46 [65]
^{110m}Ag	4 [3]	0.006 [0.0002]	N/A	47 [33]	47 [34]	86 [55]
^{125}Sb	35 [12]	0.02 [0.01]	N/A	30 [44]	96 [51]	126 [6]
^{131}I	5 [3] (1)[b]	0.00027 [0.00027][c]	1.5 [1]	10 [20]	37 [23]	45 [13]
^{134}Cs	5 [3]	0.007 [0.004]	1.4 [1]	14 [29]	37 [24]	57 [39]
^{137}Cs	7 [4]	0.006 [0.004]	1 [0.3]	11 [29]	32 [21]	52 [56]

^{140}Ba	10 [6]	0.004 [0.003]	N/A	36 [17]	24 [15]	157 [39]
^{140}La	9 [5]	0.01 [0.02]	N/A	12 [9]	34 [21]	47 [6]
^{141}Ce	8 [3]	0.002 [0.001]	N/A	19 [23]	22 [13]	63 [3]
^{144}Ce	35 [14]	0.013 [0.0096]	N/A	96 [103]	110 [70]	267 [14]
^{226}Ra	116 [69]	0.05 [0.03]	N/A	828 [654]	323 [195]	858 [51]
^{228}Ac	30 [18] 15 h	0.0127 [0.0099]	N/A	68 [33]	146 [87]	27 [12]
^{228}Th	387 [142]	0.09 [0.06]	N/A	859 [317]	944 [356]	2100 [167]
^{234}Th	618 [87] 15 h	0.159 [.0423]	N/A	1009 [378]	1300 [556]	570 [94]
^{235}U	N/A	N/A	45 [30] 15 h	N/A	N/A	N/A
^{239}Np	41 [33]	0.01 [0.009]	5 [3]	64 [44]	40 [30]	97 [71]

[a] GeLi = Germanium lithium; HPGe = High purity germanium.

[b] Two methods of analysis are done: **1)** 8 hour direct gamma isotopic analysis of a 2000 mP milk or water sample that has a method detection limit (MDL) of 3 pCi/P, and **2)** 3 hour gamma isotopic analysis of ion exchange resin after a 1500 mP milk sample is filtered through an ion exchange column that has an MDL of 1 pCi/P.

[c] The MDL for ^{131}I when analyzing a charcoal cartridge is 0.03 [0.02] pCi/m^3 based upon a 250 m^3 sample volume. If the sample volume is increased to 1500 m^3, the MDL is 0.002 [0.001] pCi/m^3.

Method detection limits of present analytical methods for selected radionuclides monitored by the KHEL Radiochemistry Laboratory. These limits are intended as guides to order of magnitude sensitivities and are calculated with a 95% level of confidence (activity will be detected 95% of the time if it is present).

Low Background Alpha and Beta Counting System					
	Water	Milk	Wipe	Soil & Sediment	Vegetation & Food Products
Minimum Sample Size	1000 ml	1000 ml	Total	0.01 kg	0.1 kg
Minimum Counting Time	200 min.	200 min.	200 min.	200 min.	200 min.
Method Detection Limit	pCi/L	pCi/L	pCi/wipe	pCi/kg-dry	pCi/kg-dry
^{89}Sr	1	2	3	200	500
^{90}Sr	1	2	4	200	500
^{131}I	1	N/A	N/A	N/A	N/A
^{228}Ra	1.2	N/A	0.3	60	N/A

Gross Beta				
	Water	Filter	Wipe	Soil and Sediment
Minimum Sample Size	200 ml	250 m^3	Total	0.001 kg
Minimum Counting Time	200 min.	100 min.	100 min.	100 min.
Method Detection Limit	4 pCi/l	0.004 pCi/m^3	2 pCi/Wipe	160 pCi/kg-dry

Gross Alpha			
	Water	Filter	Wipe
Minimum Sample Size	200 ml	250 m^3	Total
Minimum Counting Time	200 min.	100 min.	100 min.
Method Detection Limit	1 pCi/l	0.0006 pCi/ m^3	0.5 pCi/Wipe

Random Scintillation Counting System				
^{226}Ra (radium) in water				
Minimum Sample Size		1000 ml		
Minimum Counting Time		200 min.		
Method Detection Limit		0.04 pCi/l		

Liquid Scintillation Counting System			
	Tritium (^{3}H)		^{222}Rn (Radon)
	In water	In Tissue	In Water
Minimum Sample Size	10 ml	3 g	10 ml
Minimum Counting Time	100 min.	120 min.	60 min.
Method Detection Limit	350 pCi/l	1200 pCi/kg-wet	25 pCi/l